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As Genes Learn Tricks, Animal Lifestyles Evolve

By SEAN B. CARROLL

Early one evening a few years ago, I took a short hike with my wife, Jamie, in the Cockscomb Basin Wildlife Sanctuary in Belize. The large, lush reserve is known for its healthy population of jaguars, so, following closely behind our guide, we kept our eyes peeled for the elusive cats. We saw a few tracks and some claw marks on trees, but elected to leave the jungle before nightfall.

We were very near the end of the trail when we were surprised by a large snake, about six feet long, crossing directly in front of us. Belize has lots of snakes, more than 50 species. Some can get pretty large, like the boa constrictor, which is impressive but harmless.

This one was not harmless. Even in the darkening jungle, the triangular pattern on its back allowed me to identify it quickly as a fer-de-lance, the most dangerous snake in Belize.

Excited, and comfortable that I was well out of striking range, I reached into my backpack for my video camera and flipped on its “night shot” feature. I now saw the magnificent snake clearly on my LCD screen. As I tried to creep in for a closer shot, however, I felt something holding me back.

It was Jamie. She had a grip on my backpack and was concerned that my enthusiasm for snakes had overtaken my judgment. She was not convinced that we were out of range, nor that the snake would not move quickly toward us. I used the zoom and filmed from where I stood.

For me to film the snake in the dark, I had to rely on Sony’s innovation and engineering. The camera’s infrared LED source generated light with a longer wavelength than the human eye can detect; those photons then bounced off the snake and were detected by the camera’s infrared sensors and converted into an image.

For the fer-de-lance to find its prey in the dark, it also relies on infrared sensors. But that ability, which it shares with a select group of other snakes, was acquired the ol
It was evolved, of course. And recent understanding of how some snakes and c
detect infrared light is providing some striking examples of how new lifestyles
old genes learn some new tricks.

Closely related to the rattlesnake, the fer-de-lance is also a pit viper, a member of a group of venomous snakes named for the deep sensory pits between the nostrils and eyes. These specialized pits enable the snakes to detect infrared light in the form of heat.

Humans and other warm-blooded animals emit heat as infrared radiation. Pit vipers are so adept at infrared sensing that some can detect potential prey a meter away.

To understand how snakes evolved their infrared detection systems, a group of scientists led by Prof. David Julius at the University of California, San Francisco, searched for potential infrared-sensing proteins in the western diamondback rattlesnake. They looked in particular at genes active in the nerve cells that are connected to the pits, called trigeminal neurons.

They found one gene, known as TRPA1, that was 400-fold more active in rattlesnake trigeminal neurons than in other kinds of neurons. Moreover, they found that the TRPA1 gene was not highly active in the trigeminal neurons of snakes lacking pits. These two pieces of evidence suggested that TRPA1 might encode a protein involved in infrared sensing.

The TRPA1 protein was very familiar to the scientists. A few years earlier, Dr. Julius's group had identified TRPA1 as the receptor that drives our response to the molecules that give wasabi its punch, as well as to other chemical irritants, like tear gas.

The TRPA1 gene encodes a type of receptor protein known as an ion channel. In humans and other mammals, when the protein is exposed to and binds specific chemicals, the channel opens, allowing ions to flow into nerve cells and setting off a sequence of events that produces a nerve impulse.

In pit vipers, however, Dr. Julius and his collaborators discovered that the TRPA1 has evolved to be especially heat-sensitive. While the receptor is not activated in most snakes by temperatures approaching 37 degrees Celsius (98 degrees Fahrenheit, our normal body temperature), the western diamondback rattlesnake TRPA1 receptor is stimulated around 27 degrees Celsius (80 degrees Fahrenheit), creating a "thermal image" of the heat source in the snake's brain that is used to aim its strike. Pit vipers are not the only animals or even the only snakes to have evolved infrared sensing. Pythons and boas have also evolved heat-sensing pit organs on their faces, although of a different structure. Dr. Julius and his team found that TRPA1 was also highly expressed in the trigeminal neurons of python and boa pit organs, about 65-fold and 170-fold higher, respectively, than in the trigeminal neurons of other snakes lacking pits. Similarly, their TRPA1 receptors were 5 to 8 degrees Celsius more heat-sensitive than typical snakes.

In both groups of snakes, changes in the structure of the TRPA1 receptor, and the evolution of

very high levels of expression in their sensory pits, endowed the animals with sensitive infrared detectors.

The large evolutionary distance between pit vipers and pythons and boas indicates that the two groups of snakes separately evolved infrared sensing.

But TRPA1 is not the only means of infrared sensing. Dr. Julius's laboratory recently investigated the mechanism of infrared detection in another group of animals so equipped: the infamous vampire bats. This small group of blood-feeding bats also has sensory pits around the noses that the animals use to locate the warmest areas on the surface of their furry prey, where blood flow is the greatest. Dr. Julius's team found that the bats had recruited a different ion channel/ receptor called TRPV1 to become an infrared sensor.

What is especially noteworthy about TRPV1 is that it is the very same receptor that detects capsaicins, the active ingredients in chili peppers, in our neurons. It causes the familiar burning sensation when prompted. The scientists discovered that the particular form of the receptor expressed in vampire bat trigeminal neurons was much more heat-sensitive (by about 9 degrees Celsius) than either our TRPV1 receptor or the TRPV1 expressed in fruit bat neurons. The vampire bat receptor is thus tuned to detect heat in ways that other bats and mammals cannot.

Both the TRPA1 and TRPV1 genes are hundreds of millions of years old, having arisen deep in evolutionary history, while vampire bats, pit vipers, and pythons and boas are much younger species. The histories of these genes and animals, and the repeated invention of infrared sensing, demonstrate how the evolution of new abilities does not necessarily require new genes, but new variations of very old genes and new ways of using them.

In case you are eager to see such clever creatures, all three known species of vampire bats also inhabit Belize. I didn't tell Jamie then, but now she knows.